Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences

Newfoundland and Labrador Region
Quebec Region

Canadian Science Advisory Secretariat
Science Advisory Report 2011/050

UPDATED STATUS OF NORTHWEST ATLANTIC HARP SEALS, (*Pagophilus groenlandicus*)

Figure 1: Range, migratory pathways and whelping locations of harp seals in the northwest Atlantic.

Context :

Northwest Atlantic harp seals are hunted throughout their range. They are harvested for subsistence purposes by Inuit in Labrador, Arctic Canada and Greenland, and a commercial harvest occurs in the Gulf and at the Front.

Subsistence harvests are currently not regulated while the commercial harvest is regulated by a five-year management plan that ended in 2010. In addition, seals are caught incidentally in fishing gear.

Abundance of harp seals is estimated using a population model that incorporates information on removals, annual reproductive rates and periodic estimates of pup production. In the fall of 2009 the National Peer Review Committee reviewed the results of pup production surveys conducted in the 2008. They were unable to reconcile the differences between two survey estimates of the largest whelping concentration and as a result, there was considerable uncertainty in the estimates of population size.

Science has been asked to determine the best estimate of harp seal pup production in 2008 and to estimate total population size in 2008 and 2010. Science was also asked to explore the impact of different catch scenarios on the population dynamics of northwest Atlantic harp seals.

Canada

SUMMARY

- Northwest Atlantic harp seals are harvested in Canadian and Greenland waters. After averaging approximately 52,000 seals per year between 1983 and 1995, reported Canadian catches increased significantly to a range of 226,000 to 366,000 between 1996 and 2006. Catches have been significantly reduced since 2007 with a reported catch of 69,101 in 2010. Greenland catches have increased steadily since the mid 1970's reaching a peak of approximately 100,000 in 2000. Since then they have fluctuated, averaging around 85,000. Catches in the Canadian Arctic remain low (<1,000).

- This assessment relies on pup surveys completed once every four - five years combined with estimates of annual reproductive rates and removals to determine total abundance using a population model.

- Total removals of harp seals were estimated using reported catches, estimates of bycatch, primarily in the Newfoundland lumpfish fishery, and estimates of seals killed but not recovered (referred to as 'struck and lost') during harvesting in the different regions. From 1996 to 2004, high catches in Canada and Greenland resulted in average annual removals of 465,500. However total removals have declined to an annual average of 310,300 since 2005, primarily due to the lower catches in the Canadian commercial hunt.

- Annual pregnancy rates have been estimated since the 1950s. Pregnancy rates among 4 year olds are low and without trend while pregnancy rates of 5 and 6 year olds increased during the 1970s to a high of 50% and 90%, respectively and then declined to 30% and 50% respectively by the mid 1980s. Since then they have continued to decline. Pregnancy rates of seals 7 years of age and older remained high until the mid 1980s when they declined to approximately 60%. Since then, rates have fluctuated greatly from a low of 40% in 2004 to a high of 74% in 2008. The overall general decline and marked variability in reproductive rates suggests that density-dependent factors are influencing the dynamics of this population.

- A visual survey of the largest whelping concentration off Newfoundland flown on 10 March 2008 produced an estimate of 589,400 (SE=49,500) pups while a photographic survey of the same concentration on 16 March obtained an estimate of 1,161,600 (SE=112,300). The result from a second photographic survey of this concentration carried out on 12 March (1,026,997, SE=280,445) was similar to that obtained from the 16 March photographic survey suggesting that the 10 March visual survey was an under-estimate.

- Combining the estimates from the two photographic surveys at the Front (1,142,985, SE=104,284) with estimates of pup production in the southern Gulf (287,033, SE=27,561), the northern Gulf (172,482, SE=22,287) and another small group at the Front (23,381, SE = 5,492), resulted in a 2008 total pup production estimate of 1,630,300 (SE=110,400, CV=6.8%).

- Assuming exponential population growth, a population model, was fitted to the survey data and smoothed reproductive rates, resulting in a total population estimate of 8.0 million (95% CI 6.77 to 9.26 million) animals in 2008. However, the model fit to the

recent pup survey data was very poor owing to large fluctuations in annual reproductive rates among mature females which likely produced sharp changes in pup production in 2004 and in 2008.

- A model assuming density-dependent population growth, environmental carrying capacity of 12 million and annual reproductive rate data was fitted to the survey data. This approach provided a better fit to the pup survey data resulting in a total population estimate of 8.11 million (95% CI 7.34 to 8.89 million) in 2008. If a higher environmental carrying capacity of 16 million animals is assumed, then the estimated population in 2008 would be 8.73 million (95% CI=7.82 to 9.83 million).

- The future trend in the population is difficult to predict because of uncertainty associated with reproductive rates and the model formulation used to describe the dynamics of this population. Depending on the model approach and reproductive data used, the 2010 population would lie between 8.61- 9.55 million (95% CI 7.80 to 10.80 million) animals.

- Science was requested to examine a variety of harvest scenarios to determine their impacts on the population. Annual harvests of up to 400,000 animals would continue to respect the management plan over the next three years assuming that ice related mortality of young of the year is on average about 30% above normal. Higher levels might be acceptable, but are sensitive to assumptions concerning population growth. Very poor ice conditions are expected for 2011, which may result in higher mortality, but under such conditions catches are expected to remain low.

- The current population is at its highest level seen in the 60 year time series. However, uncertainty associated with how the current population is changing and the variability in reproductive rates as well as uncertainty in harvest levels in Greenland, complicates efforts to model future trends in this resource. It is recommended that the frequency of the pup production surveys be increased.

INTRODUCTION

Aerial surveys to estimate pup production were carried out in March 2008 and analysis completed in 2009 and 2010. Updated data on reproductive rates and removals were also available. Using these data, the current status of northwest Atlantic harp seal population was re-assessed. The estimates of total population presented here are based upon a population model that incorporates pup production estimates up to 2008, reproductive data to 2008, updated catch data for the Canadian commercial (2010) and Greenland (2007) hunts, and assumed values of ice-related mortality. Northwest Atlantic harp seals are managed under the Atlantic Seal Management Strategy. It is considered to be a data-rich population and is managed to maintain an 80% probability that the population remains above a precautionary reference level (N_{70}) which is defined to be 70% of the maximum estimated population size.

Science was requested to provide advice on whether the following catch scenarios respect the current management plan over the next three years. The scenarios were:

A. 320,000 (2011), 320,000 (2012), 320,000 (2013),
B. 300,000 (2011), 300,000 (2012), 300,000 (2013),
C. 320,000 (2011), 300,000 (2012), 275,000 (2013), and

D. 400,000 (2011), 400,000 (2012), 400,000 (2013)

Species Biology

The Northwest Atlantic population of harp seals summers in the Canadian Arctic and Greenland. In the fall, most of these seals migrate southward to the Gulf of St. Lawrence ("Gulf"), or to the area off southern Labrador and northern Newfoundland ("Front") where they give birth in late February or March on medium to thick first year pack ice. Male and female harp seals are similar in size with adults averaging 1.6 m in length and 130 kg in weight. Females nurse a single pup for about twelve days, after which adults mate and then disperse. The pup, known as a whitecoat, moults its white fur at approximately three weeks of age after which it is referred to as a beater. Older harp seals form large moulting concentrations on the sea ice off northeastern Newfoundland and in the northern Gulf of St. Lawrence during April and/or May. Following the moult, seals disperse and eventually migrate northward. Small numbers of harp seals may remain in southern waters throughout the summer while a portion of the population remains in the Arctic.

The Hunt

Harp seals have been hunted commercially since the early 18th century. Catches off Newfoundland, and in the Gulf of St. Lawrence, increased significantly after 1820, peaking at over 740,000 seals in 1832. This harvest was directed towards the oil market and was likely a mixture of pups and sexually mature females. Catches ranged from 200,000 to 600,000 throughout the remainder of the 1800s, averaging 360,000 from 1818 to 1913. During the First World War catches declined to less than 100,000 and averaged about 150,000 from 1919 to 1939. Commercial harvesting was greatly reduced during World War Two, but then increased rapidly reaching 450,000 in 1951, averaging about 288,000 seals per year from 1952 to 1971 (Fig. 2).

The first Total Allowable Catch (TAC) was set in 1971 at 245,000. It varied until 1982 when it was set at 186,000 where it remained until 1996. From 1972 to 1982, the average annual catch was approximately 165,000 seals. Prior to 1983, the large-vessel take of white-coated pups on the whelping patch accounted for the majority of the harvest. A ban on the importation of whitecoat pelts implemented by the European Economic Community in 1983 severely reduced the market, ending the traditional large-vessel hunt. From 1983 to 1995 catches remained low, averaging ~50,000 per year. The quota was increased in the mid 1990s and an average of 262,000 seals was taken annually between 1996 and 2002. From 2003-06, a multiyear quota was set at 975,000 seals (average 325,000 per year) with a maximum of 350,000 in any two years and the remainder in the third. A total of 985,312 animals were taken over the three years of this plan (Table 1). The multiyear quota system was not renewed in 2006 when an annual quota of 335,000 was set. The quota was subsequently reduced in 2007 to 270,000 due to poor ice conditions and to ensure the population was maintained above the Precautionary Reference Level. It was increased slightly in 2008 to 275,000 and again in 2009 to 280,000. The 2010 TAC was increased significantly to 330,000. Although the quota was exceeded in 2006, catches in 2007, 2008 were ~80% of the TAC and only ~ 27% in 2009. A further reduction in effort resulted in a 2010 catch of 69,101 which is 21% of the TAC. Young of the year (YOY) seals that have moulted their whitecoat ('beaters') make up over 95% of the harvest since 2000, and 99% of the catch in 2010.

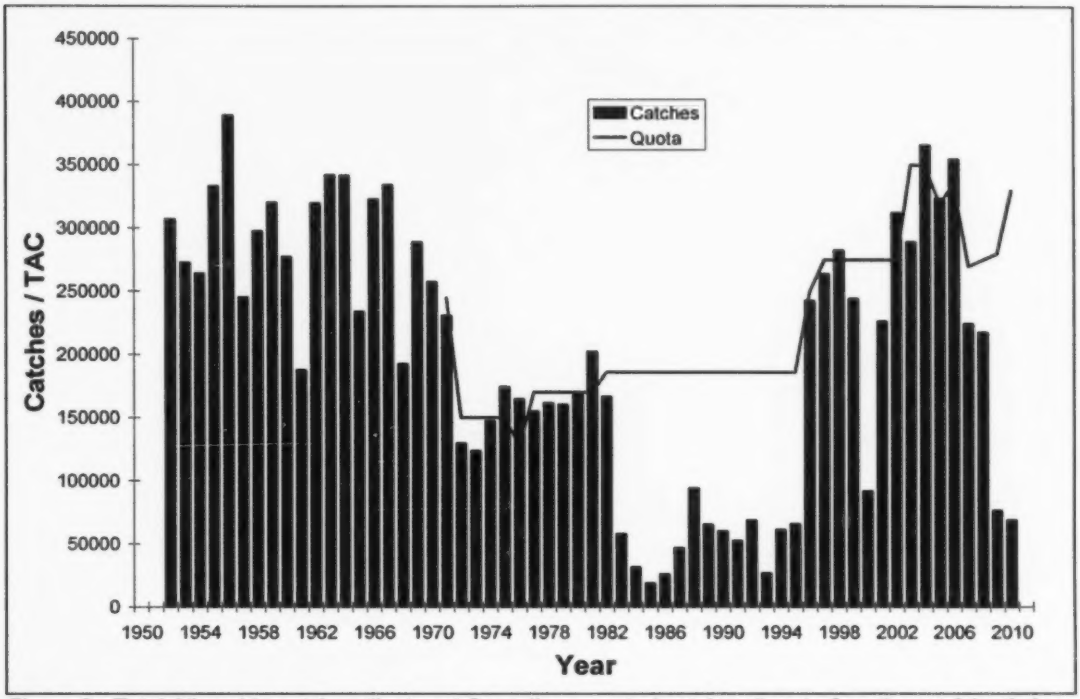

Figure 2: Total Allowable catches (line) and Canadian reported catches (bars) of northwest Atlantic harp seals and quotas, 1952 to 2010.

Harp seals are currently hunted by land-based sealers in both the Gulf and Front areas during the winter. Current regulations do not allow the hunting of adults in the whelping patch, the harvest of whitecoats, or the use of vessels greater than 20 m in length.

Table 1: Canadian commercial (plus TAC) and Greenland catches of harp seals (,000s), 2000-2010.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Canada											
TAC	275	275	275	350[1]	350[1]	319.5	335	270	275	280	330
Catch	92.1	226.5	312.4	289.5	366.0	323.8	354.9	224.7	217.8	76.7	69.1
Greenland											
Catch	98.5	85.4	66.7	66.1	70.6	91.7	92.2	82.8	N/A	N/A	N/A

[1] Maximum annual catch under the three year management plan, totalling 975.

Prior to 1980, catches of Northwest Atlantic harp seals in Greenland were consistently less than 20,000 animals (Fig 3). Since 1980, Greenland catches increased relatively steadily to a peak of over 100,000 in 2000. From 2002 through 2004, catches decline to between 66,000 and 70,000, but increased to slightly over 90,000 seals in 2005 through 2007. Slightly over 82,000 harp seals were reported caught in 2007, the last year for which we have data. Seals of all ages are taken in Greenland with the majority being over one year of age.

Catches in the Canadian Arctic are not well documented, but appear to be low with likely fewer than 1,000 harp seals taken annually in recent years (Fig 3).

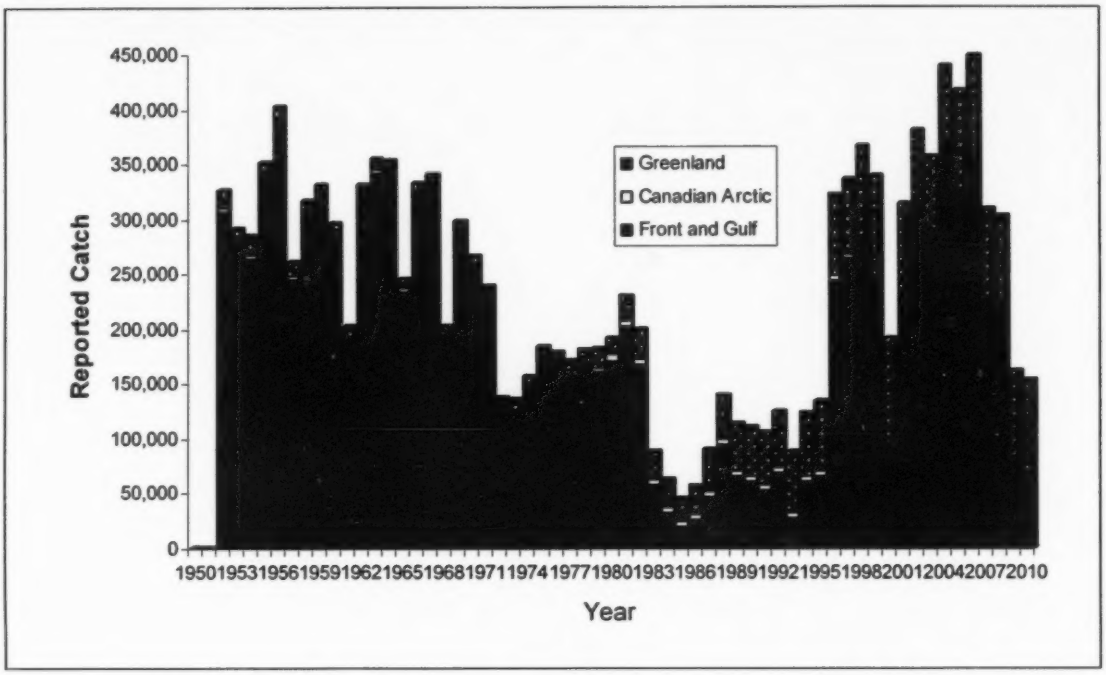

Figure 3: Reported commercial and subsistence catches of harp seals in the northwest Atlantic 1952-2010. Totals do not include seals killed but not landed, or those killed as bycatch in commercial fisheries. Greenland harvests since 2007 are assumed.

Other Sources of Human-Induced Mortality

In addition to reported catches, some seals are killed, but not recovered or reported (referred to as 'struck and lost'). Loss rates of young seals during the large vessel, whitecoat hunt (prior to 1983) are considered to be low (~1%). Estimates of the additional mortality caused by struck and lost for YOY seals which make up the majority of the current harvest in Canada appear to be 5% or less (assumed 5%) while losses of older seals are higher (assumed to be 50% of those killed). This higher figure is also applied to catches in the Canadian Arctic and Greenland when estimating total removals (Fig. 4).

Harp seals are also taken as bycatch in fishing gear. The Newfoundland lumpfish fishery is thought to be responsible for the largest bycatch mortality of seals. Seals are taken in other fisheries although the numbers caught have not been estimated. Estimated numbers of seals taken annually as bycatch in the lumpfish fishery were generally below 1,000 seals prior to 1976; however, by the late 1980s and early 1990s catches had increased to over 10,000 in some years (Fig. 4). Peak catch levels occurred from 1992-96 with an average take of 29,431 seals annually. Although catches have been variable in recent years, less than 5,500 seals were taken in 2003. A small number of harp seals (<500/yr) are taken in fishing gear in the northeastern United States.

To estimate total removals, reported catches in Canada and Greenland are combined with estimates of bycatches and struck and lost. Between 1952 and 1971, removals averaged 388,000 seals, primarily due to commercial catches in southern Canada. Removals fell with the imposition of Canadian quotas in 1971, averaging just over 226,000 from 1972 to 1982. The decline of Canadian

catches between 1983 and 1995 resulted in fewer annual removals (average 176,000) although the contribution of struck and lost to the total increased due to the higher level assumed for the Greenland hunt. Between 1996 and 2004, higher catches in Canada and Greenland resulted in average annual removals of 468,500. Since 2007, the level of total removals has declined due to lower catches in the Canadian commercial hunt. Total removals were estimated to be approximately 250,000 in 2010 (Fig. 4). Young of the year have declined from approximately 65% of the total removals in recent years to 42% in 2010 due to the increased importance of the Greenland hunt.

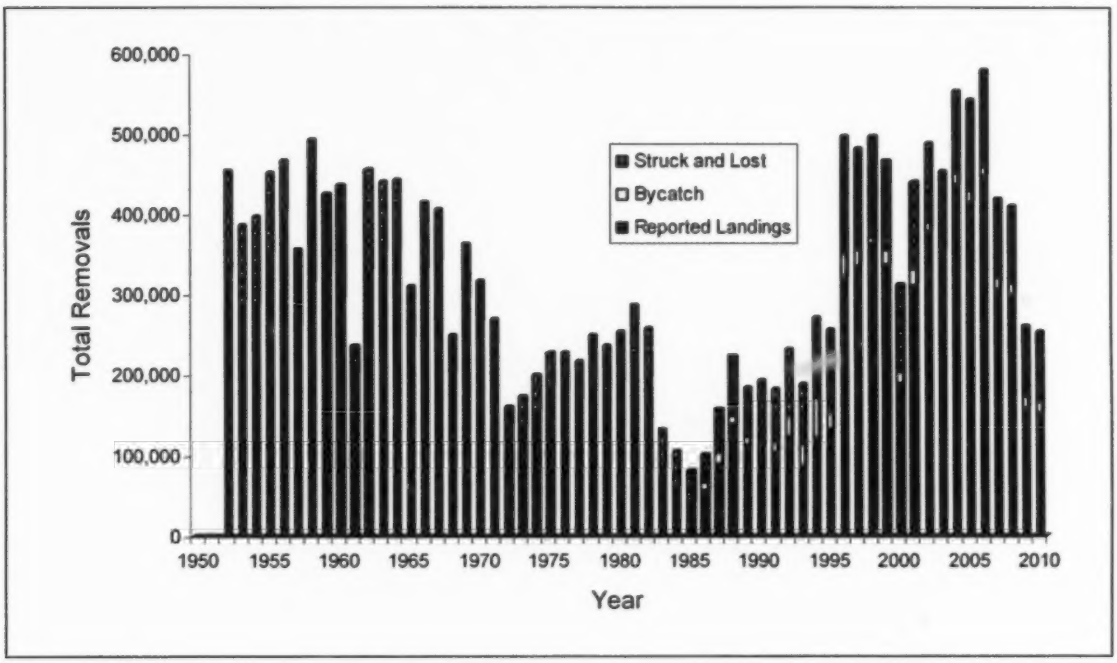

Figure 4: Total removals of Northwest Atlantic harp seals, 1952 to 2010.

ASSESSMENT

Resource Status

The number of harp seal pups born in a year is estimated periodically from aerial surveys conducted in the spring, when the seals have hauled out onto the ice to have their pups. Estimates of total population are based on a population model that incorporates these estimates of pup production with information on reproductive rates (the proportion pregnant each year), catches in Canada and Greenland, by-catch and struck and lost as well as information on unusual pup mortality due to poor ice conditions.

Pup Production

In the past, pup production has been estimated from catch data, mark-recapture experiments, and aerial surveys. Estimates for the mid to late 1970's ranged from approximately 250,000 to

500,000. The Royal Commission on Seals and Sealing in Canada concluded that pup production in 1978 was about 300,000-350,000 and the total population was about 1.5-1.75 million. Aerial surveys, off the Front and in the Gulf of St. Lawrence, resulted in pup production estimates of 580,000 (± 78,000) pups in 1990, 703,000 (± 125,000) in 1994, 998,000 (± 200,000) in 1999 and 991,400 (± 114,100) in 2004 (Fig. 6). Total pup production increased throughout the 1980s and 1990s (Fig. 6), but appeared to have slowed as the 2004 estimate was not significantly different from the 1999 estimate. This stabilization of pup production was thought to be due, in part, to the increased catches of young seals since 1996 and was consistent with previous model predictions.

Photographic and visual aerial surveys were flown off Newfoundland and in the Gulf of St. Lawrence during March 2008 to estimate current pup production. Surveys of five whelping concentrations were conducted between 1 and 16 March, resulting in estimates of pup production of 287,000 (SE=27,600, CV 9.6%) in the Southern Gulf and 176,800 (SE=22,800, CV=12.9%) in the Northern Gulf. A small concentration at the Front was estimated to contain 23,400 (SE=5,500, CV=23.5 %) pups. The visual survey of the largest concentration at the Front on 10 March resulted in an estimated pup production of 589,400 (SE=49,500, CV=8.4%) whereas a photographic survey on 16 March estimated 1,161,600 (SE=112,300, CV=9.7%) pups.

An additional photographic survey was flown on 12 March. Given the differences obtained between the visual and the 16 March survey, this additional survey was analyzed to determine which estimate was more likely to be correct. Analysis of these images resulted in a total pup production of 1,027,000 (SE=280,400, CV=27.3). The two photographic estimates were similar and it was concluded that the visual survey was an underestimate. The photographic survey estimates were combined with the estimates obtained from the other whelping concentrations and resulted in the estimate of total pup production of 1,630,300 (SE=110,400, CV=6.8) for Northwest Atlantic harp seals in 2008.

The visual survey could produce an underestimate if pups were born after the visual survey was flown, the observers were overwhelmed, or if a large concentration of pups was missed. Staging surveys, which covered all of the areas surveyed, indicated that no significant pupping occurred after the 10 March survey. It is not thought that observers were overwhelmed during the survey, leaving the possibility that animals were missed possibly to the east of where the visual survey transects ended. During the photographic surveys, additional transects were flown to the south as seals were encountered. These pups accounted for a large proportion of the estimate, particularly on 16 March; the estimated pup production obtained from the wide (4 and 6 nm) spaced transects at the southern edge of the concentration was just under 400,000 pups (CV = 24%) which would account for most of the difference between the surveys.

Reproductive Rates

Pregnancy rates and mean age of maturity have varied considerably since the 1950s. In the mid 1950s the average age at which harp seals matured was 5.8 years, whereas, from the late 1970s through the mid 1980s they matured a year younger (~4.5 years of age). By the mid 1990s, the mean age of maturity (MAM) increased to 5.7 years, where it remained for several years. With the exception of 2000, MAM increased during the early 2000s reaching a time-series high of 6.1 in 2005/2006. In 2007/2008, the MAM declined to 5.3 years, although sample sizes in important age classes (3-8 years of age) were small.

Reproductive tracts from females collected during October-February provide information on late-term pregnancy rates since the mid 1950s. These data were smoothed to estimate annual age-specific pregnancy rates (Fig. 5). Rates among 4 year olds remained low (<10 %). Among seals aged 5 and 6 years, age-specific pregnancy rates initially increased during the 1970s, but declined by the mid 1980s to levels similar to, or lower than, those seen in the 1960s. The percentage of mature females (7+ years) that were pregnant increased from the mid 1950s (85%) to a peak of 98% in the mid 1960s. It then declined to approximately 60-70% during the early 1990s and has been highly variable ever since. The lowest rate in the time series occurred in 2004 (40%) while the rates in 2007 and 2008 (75.3 and 73.8%, respectively) were the highest seen in 10 years. In previous assessments, this high inter-annual variability was associated with sampling variability, consequently reproductive rates were smoothed. The continued collection of the reproductive rate data has allowed for a more in-depth analysis and although sampling does contribute to the observed variability, the marked between year changes appear to reflect real changes in reproductive rates in the population.

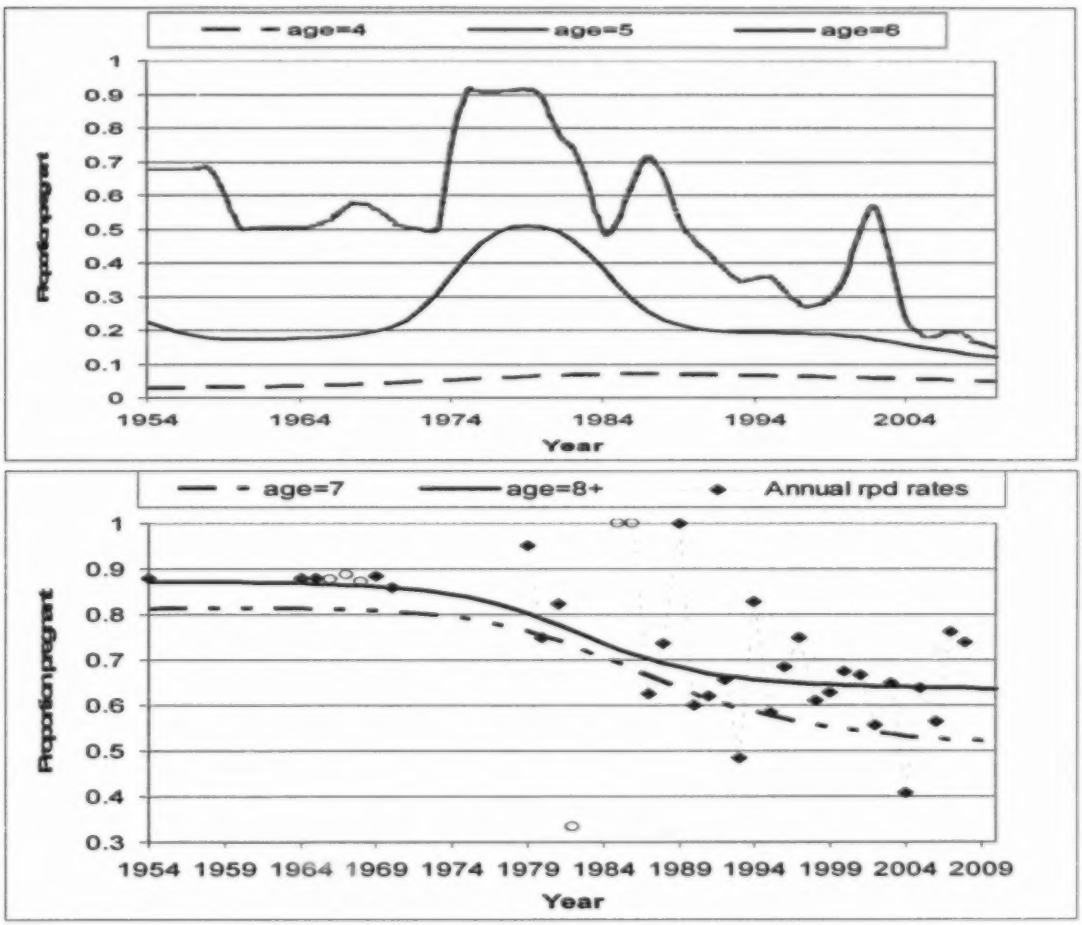

Figure 5: Smoothed estimates of age-specific pregnancy rates of northwest Atlantic harp seals, 1960 to 2008. Ages 4 to 6 (top) and 7 and 8+ years (bottom). Points show annual rates for animals aged 8+ years, open circles represent sample sizes of less than 10 animals.

Total Population Size

A two parameter model that includes information on age-specific reproductive rates, ice-related mortality of young of the year seals (YOY), and human removals was used to estimate population size and evaluate the impacts of future harvests on the population. The model was fit to independent estimates of pup production by adjusting the starting population size and adult mortality to minimize the differences between observed pup production and predictions from the model. Over the past two decades, the same basic population model has been used, although over time, this model has been refined in the way that it incorporates reproductive data and to explicitly include more sources of mortality and uncertainty in estimates of total population size.

The model uses data on pup production since 1952, reproductive rates since 1954, human-induced mortality (catches, by-catch in fishing gear, and struck and lost) since 1952 and mortality of young seals due to poor ice conditions since 1969 to estimate pup production and total population size from 1952 to 2010.

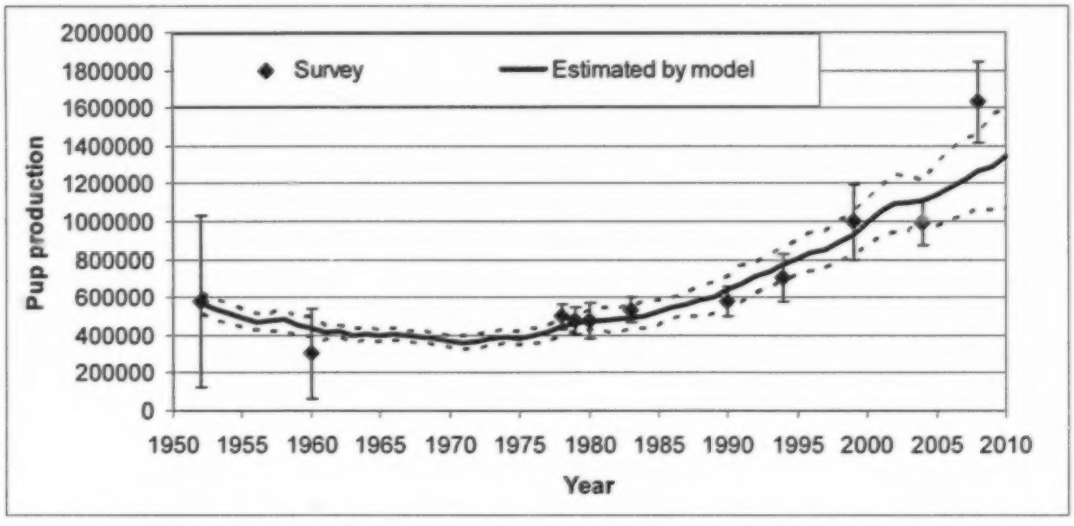

Figure 6: Independent (±95% CI) and model (±95% CI, line) estimates of pup production 1952 to 2010 assuming smoothed reproductive rates and exponential growth in the population.

The population model fit to the aerial survey estimates using smoothed reproductive rates was very poor due to high inter-annual variability in the reproductive rates (Fig. 6). However, the smoothed approach provides a means of interpolating rates for years where there are gaps in the reproductive data and describes the general trend in reproductive rates. Using this model, and assuming exponential population growth, the total population was estimated to have risen from 7.36 million (95% CI 6.48-8.08 million) animals in 2004 to 8.04 million (95% CI 6.77 to 9.26 million) animals in 2008, for an annual growth rate of 2.0%. The population is predicted to have increased to 9.11 million (95% CI 7.49 to 10.61 million) animals in 2010 (Fig. 7).

The Northwest Atlantic harp seal population has increased significantly over the past four decades. The general decline in reproductive rates over this period, as well as a decline in size at age suggests that density dependent changes are affecting the dynamics of this population. It

is likely that juvenile survival should also be declining, but mortality rate data are not available. It is very difficult to determine the exact relationship between the current population and the environmental carrying-capacity (K) level. Values of 12 million and 16 million animals were accepted as reasonable proxies of K to describe the current dynamics of the population, recognizing that these values may change as more information becomes available. Assuming that K= 12 million animals, and incorporating annual reproductive rates (rather than smoothed rates used previously) into this model results in an estimated total population size in 2004 of 7.21 million (95% CI=6.67 to 7.83 million) animals increasing to 8.11 million (95% CI=7.34 to 8.90 million) animals in 2008 and to 8.61 million (95% CI =7.80 to 9.43 million) animals in 2010, an annual rate of increase of 3% since 2004. If K=16 million animals is assumed, then the model estimates a 2004 total population size of 7.59 million (95% CI=7.0 to 8.29 million) animals increasing to 8.73 million (95% CI=7.82 to 9.83 million) animals in 2008 and to 9.55 million (95% CI =8.51 to 10.80 million) animals in 2010, an annual rate of increase of 4% since 2004. Prior to 2010, the population trajectory from the density dependent model and exponential growth models were similar, although the density dependent model using annual estimates of reproductive rates fit the recent survey estimates better than the exponential model using the smoothed reproductive rates (Fig. 7).

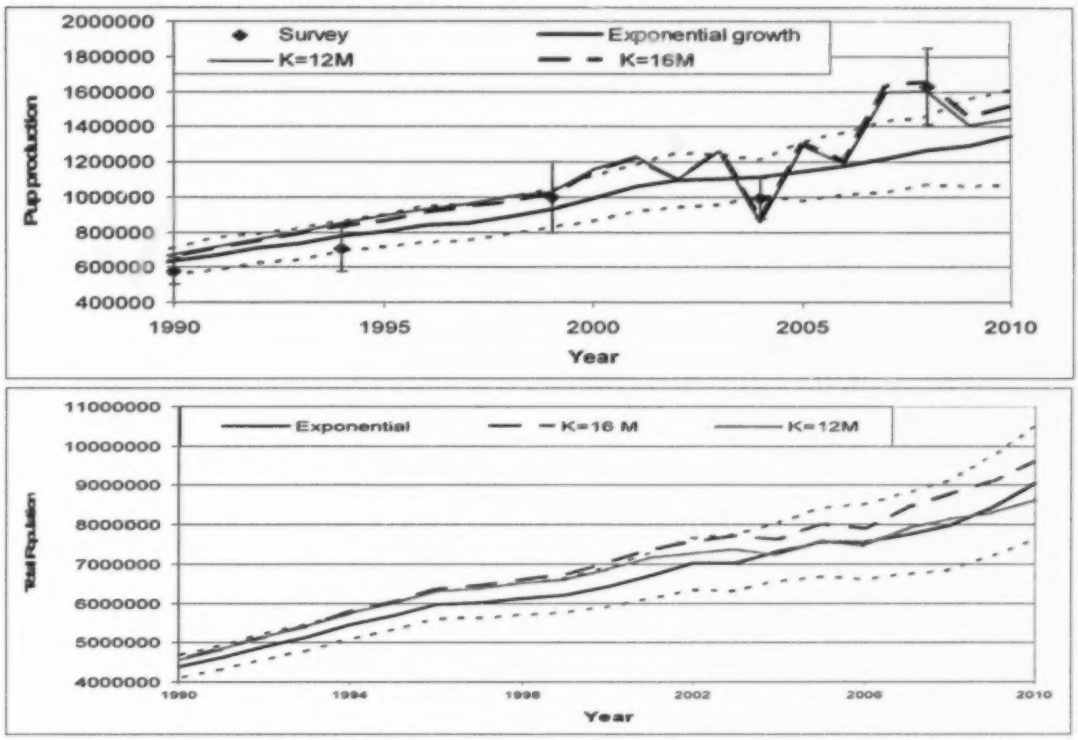

Figure 7: Aerial surveys (±95% CI) and model estimates of pup production (top). The model was fitted to the data assuming exponential growth (±95% CI), and assuming K=12 million and 16 million. Estimated total population for Northwest Atlantic harp seals for 1990-2010 assuming exponential growth (±95% CI), or K= 12 million or K=16 million (bottom).

Catch options

Fisheries and Aquaculture Management requested that four catch level scenarios, each for three years, be examined within the context of the management plan that ends in 2010 (Table 2). These were examined within the context of a population that continues to grow exponentially, as well as one that is undergoing density-dependent changes in its population dynamics.

Table 2: Catch scenarios used to explore the impact of different Canadian catch levels on northwest Atlantic harp seals.

Scenario	2011	2012	2013
A	320,000	320,000	320,000
B	300,000	300,000	300,000
C	320,000	300,000	275,000
D	400,000	400,000	400,000

For the projections, by-catch and removals in Arctic Canada were assumed to be the same as in 2009. As in the past, the Greenland harvest was assumed to vary between 70,000 and 100,000 with an average of 85,000 and the Canadian commercial catch is assumed to consist of 95% YOY. Over the last decade there has been an increase in the frequency of years with poor ice conditions which likely resulted in increased mortality among young of the year. In previous years, the impacts of different harvest levels were evaluated assuming that YOY mortality had increased as a random variable with an average of 12% per year. This mortality factor was increased to an average of 30% (range 0-45%) per year, reflecting the mortality assumed in recent years, and was applied to the projections. It was also assumed that reproductive rates remained unchanged from 2009 onwards.

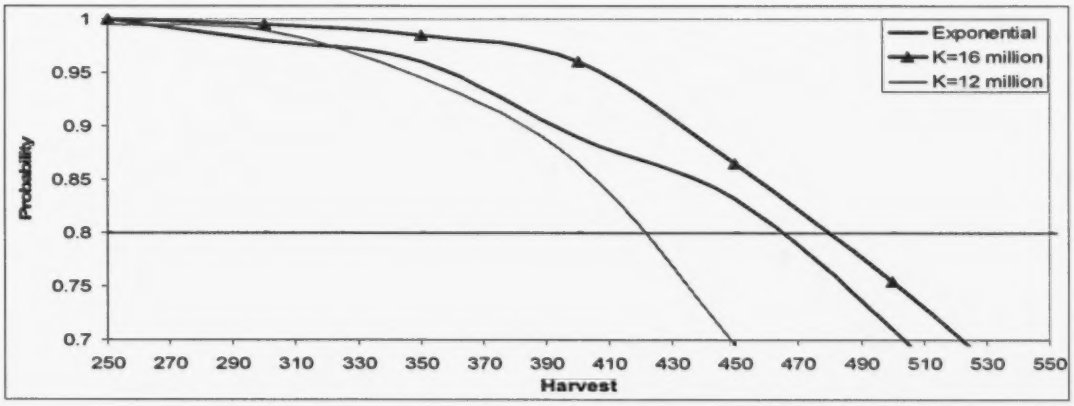

Figure 8: Probability of the population remaining above N_{70} under different harvest levels and model assumptions during the next three years of the management plan. The management objective is to maintain an 80% probability that the population above N_{70}.

Harvest levels that would continue to respect the management plan varied according to the model formulation used. Under all scenarios examined, harvest levels over the next three years of up to 420,000 animals annually, would respect the management objectives to maintain an

80% probability that the population would not fall below N_{70} during this period, including under conditions of increased natural mortality (Figs. 8, 9). Ice conditions in 2010 were extremely poor, and only 69,100 animals were taken in the Canadian commercial hunt. If extremely poor ice conditions are encountered again in 2011, then given current markets it is unlikely that harvests would exceed 100,000 animals. Under such conditions annual harvests of 400,000 animals beginning in 2012 would still respect the management plan.

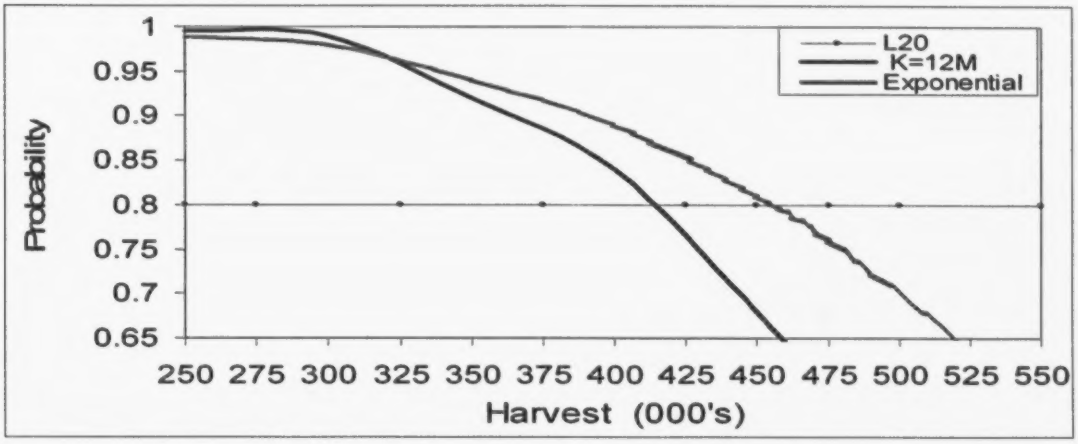

Figure 9: Probability of the population remaining above N_{70}, under different harvest levels in 2012, 2013 and 2014, if ice conditions in 2011 result in pup mortality of 50% prior to the hunt starting and 100,000 animals are taken in 2011. Model runs assumed exponential population growth and smoothed reproductive rates or assumed density-dependent population growth with K=12 million.

Sources of Uncertainty

Pup production estimates are a critical component of the harp seal population model. The 2008 estimate was significantly higher than the 2004 estimate. This high estimate appears to be largely due to high reproductive rates observed in 2008. Analysis of the reproductive data indicates that there can be considerable interannual variability in these rates although the factors affecting this variability have not been identified. Nonetheless, the general downward trend and high variability in the annual reproductive data indicates that density-dependent factors are likely affecting the dynamics of this population and that annual data are required by the population model to estimate pup production, particularly in years when surveys are flown. With survey intervals of 4-5 years it is not possible to determine environmental carrying capacity for this population (K), or how rapidly the population is approaching K. This uncertainty affects our ability to model future trends in pup production, population trends and harvest impacts. Harp seals are pelagic and undertake seasonal migrations between an Arctic ecosystem and a north Atlantic ecosystem. Availability of food resources and carrying capacity in these two systems are not known and likely vary. The differences in predicted population growth and trajectories between different model formulations increase as we project further into the future. During this assessment, K=12 million and K=16 million animals were selected as reasonable values to reflect how the dynamics of the population might be affected under different harvest scenarios if the population was approaching its carrying capacity K (K=12 million) or if the population had not yet reached carrying capacity, but was also no longer growing exponentially, yet remained some distance from carrying capacity (K=16 million). Historical reconstructions of

the population suggest that the lower value for K used here is more reasonable, but we cannot distinguish between the two possibilities presented here at the current time. Increasing the frequency of surveys over the next decade from the current 4-5 years to 3 years would allow us to improve our understanding of the dynamics of this population, particularly if changes in other environmental conditions (e.g. ice) are also occurring.

Additional uncertainty is associated with the catch data and factors applied to correct the catch data for animals that are killed, but not recovered (struck and loss). If these correction factors are too high, the population model will produce estimates of adult mortality that are too low, although the estimates of total population should not change significantly.

Removals have been estimated since 1952. However, the accuracy of reported catches, particularly the subsistence catches in the Canadian Arctic and Greenland, is unknown. Also, there is uncertainty about the ages of seals killed in the various catches and the estimates of by-catch in Canadian fisheries. Additional catches likely occur in other fisheries and are assumed to be small, but these have not been quantified.

The Greenland harvest has varied greatly over the last decade and was reported to be 82,000 in the most recent data (2007). This level is greater than the Canadian commercial catch in 2010 (Table 1). The Greenland harvest is not limited by quota; therefore when estimating the impact of future catches, we entered the Greenland harvest into the model as a uniform function with a range of 70,000 to 100,000 for a mean harvest of 85,000 animals. Also, there is considerable uncertainty in the age structure, and level of struck and lost, that occurs in this harvest. Given the level of harvest and the higher proportion of older animals taken, the Greenland harvest has an important impact on the population dynamics of northwest Atlantic harp seals. Each of the projections were modelled assuming that the level of subsistence catch in the Canadian Arctic, by-catch in fishing gear and the age structure of the harvest remained unchanged. Current estimates of these catches are not available.

The current assessment model estimates natural mortality rates to fit observed data on reproductive rates and total removals to survey estimates of pup production. The model assumes that mortality does not change over the projection period and is constant for seals one year of age and older. However, natural mortality is likely to have changed over the time and with age. Some of this change may be accounted for by assuming density dependent changes in pup mortality, but independent estimates of mortality are needed to verify model predictions and to improve information concerning the dynamics of this population.

Climate change may result in reduced availability or thickness of suitable ice in the areas traditionally used by harp seals to give birth and nurse their pups. Also, some climate models predict an increased frequency of storms during the nursing period. These climatic changes may result in increased mortality of pups or changes in whelping locations which can affect our ability to provide accurate predictions of future abundance.

CONCLUSIONS

The Northwest Atlantic harp seal population has increased fourfold since the 1970s. A general decline in age-specific reproductive rates, mean age of maturity and growth rates suggest that density dependent factors are affecting the dynamics of this population. At the same time, there is very high interannual variability in reproductive rates and above average rates in 2008,

contributed to the observed increase in pup production in 2008, compared to the 2004 survey. The available data do not allow us to adequately describe the density-dependent relationships affecting the dynamics of this population. Currently surveys are flown every 4-5 years. Additional pup abundance estimates, including reducing the interval between surveys as well as age-specific reproduction data are needed to improve our understanding of the dynamics of this population. Because of the importance of understanding changes in reproductive rates, it is important that adequate samples be collected to determine annual late term pregnancy rates, particularly in survey years.

OTHER CONSIDERATIONS

Subsistence harvests in Greenland and Arctic Canada are currently not regulated. Harvest levels in these areas, particularly in Greenland, can have a significant impact on the population dynamics of this population.

SOURCES OF INFORMATION

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, National Advisory Meeting of November 22-26th, 2010 on National Marine Mammal Peer Review Committee Meeting (NMMPRC). Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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